MODERN AND LATE PLEISTOCENE GLACIAL STUDIES IN THE CENTRAL ANDES OF PERU AND BOLIVIA: APPLICATION OF SATELLITE REMOTE SENSING AND DIGITAL TERRAIN ANALYSIS

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by
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Changes in the glaciers of the central Andes provide insight into changes in the region's climate on timescales ranging from decades to tens or hundred of thousands of years. Satellite remote sensing was used to map the current extent of glaciers and snow cover as well as the maximum extent glaciers reached during the late Pleistocene. The former extents of glaciers were reconstructed from the position of late Pleistocene moraines. Between 15° and 22° S, the central Andes contained approximately 11,000 paleo-glaciers with an area of 29,800 km^2 and an estimate volume of 3700 km^3.

These reconstructed glaciers, combined with the cirque floor elevations in Peru, were used to determine the late Pleistocene snowline for the central Andes which was 500 to 1200+ meters lower than at present. Mass balance modeling shows the consistent 1200+ meter snowline depression observed in the humid portions of the central Andes to be consistent with 5° to 9° C cooling. Extensive glacier expansion in the arid western portion of the central Andes, where the elevation of glaciers today is limited by precipitation, indicates wetter conditions existed as well. The temperature estimate is in good agreement with other paleoclimate proxies from

continental sites in South America, but disagree with current estimates of late Pleistocene sea surface temperatures which indicate a 1 to 2° C cooling.

Modern glaciers in the central Andes are presently in a state of rapid retreat. This shrinking has economic implications as glaciers are a valuable water resource. However. no comprehensive monitoring program exists. The ablation and accumulation zones, as well as the transient snowline, were mapped at two tropical sites: Zongo Glacier, Bolivia, and the Quelccaya Ice Cap, Peru, using spectral mixture analysis applied to Landsat Thematic Mapper. Because the transient snowline is a proxy for the equilibrium line altitude (ELA), this technique shows promise in enabling the relative health of many more glaciers to be monitored. Incident direct and diffuse shortwave was also modeled for a portion Cordillera Real, Bolivia. Modern glaciers are found in areas of the landscape receiving the lowest amounts of incident shortwave radiation.

BIOGRAHICAL SKETCH

Born the son of an itinerant mule-driving rural pastor, Andrew was raised in variety of Iowa landscapes which could be easily distinguished by varying degrees of flatness. Despite being proficient in basketball and track, 'Gruesome Drewsome' was the nerd of Farragut Community High. Upon graduating from high school, Andrew broke free of the Republican confines of rural Iowa and set off to experience city life in St. Paul, MN. Here Andrew enrolled in Macalester College, which was reputed to be the most liberal and by far the best small college in Minnesota.

While at Mac, Andrew majored in geology, geography, and environmental studies and minored in arguing with tree-huggers. During his 'Mac' days, Andrew encountered the world of remote sensing and spent many hours in a windowless lab cranking away on a MicroVax II, thus remaining a nerd. Andrew had just applied to Cornell, when a then Cornell graduate student - Karl Wirth, showed up for a job with glossy Landsat Thematic Mapper images of Alaska. Karl told Andrew about a new EOS project investigating the Andes and told Andrew to talk to a certain Bryan Isacks. Andrew was also told not to worry if Bryan sounded a little strange because he really was an okay guy.

Not surprisingly, Karl got the job and Andrew headed off to Cornell. During the next six years Andrew would spend a good deal of time in a windowless lab making pretty pictures of Landsat imagery, but assumes no

responsibility for the psychedelic ones. It is safe to assume he remains a nerd.

Andrew went to Cornell for three reasons: (a) to see the glacial geomorphology of the northeastern United States, (b) to work with satellite remote sensing, and (c) work in the mountains. Despite concerted effort, he seems to have succeeded doing all three. Upon arriving at Cornell, Andrew was stupefied to discover that people seemed most interested in the 'flat' parts of the Andes and Himalayas! He decided he had to see these mountains and high plateaus for himself. As it turns out, both Andrew and his Father have come to love the Bolivian Altiplano, as it seems like home - complete with donkeys - but much better vistas!

Before Andrew embarked to Cornell, members of the Macalester College Geology Department said that they were getting the better end of the deal because, 'We landed a Wirth for a Wirth-less'. Andrew hopes this has turned out not to be the case.

DEDICATION

This thesis is dedicated to everyone who has helped me along the way, but especially to my father the Reverend Doctor Carl E. Klein.

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Without the encouragement and support I received from the Macalester Geology Department it is doubtful I would have made it this far. I know I would not have made it anywhere without the support provided by

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